RODENT AND BIRD PROBLEMS IN AGRICULTURE AND THEIR MANAGEMENT IN DEVELOPING COUNTRIES[1]

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ABSTRACT

Many species of rodents, birds, and other vertebrate species cause serious damage to agricultural crops. Global damage by vertebrate pests is calculated in hundreds of millions of dollars annually. Types of economic losses caused by rodents and birds and some methods and materials used to manage vertebrate damage problems are described.

Types of damage situations are variable since rodent and bird pests tend to be opportunistic and wide ranging in their activity. Damage is often seasonal, unevenly distributed, and difficult to predict. Important bird pest damage situations involve merging (primarily in Latin America) and maturing (in Africa) grain, oilseeds (in Asia and Latin America), and fruits (worldwide). Primary rodent pest damage situations include emerging and maturing grain (worldwide), coconut (Southeast Asia and Pacific Islands), sugarcane (Latin America), and root crops (worldwide).

Management of these damage situations requires different methods and approaches depending on the pest, the crop, and the agroecosystem. The effectiveness of potential crop protection methods in many situations has yet to be evaluated. Attempts to resolve rodent and bird problems have included physical, biological, and chemical methods.

Management programs require consideration of a variety of biological, ecological, social, and economic factors. Continuing efforts should be made by vertebrate specialists in crop protection to plan research beyond traditional areas.

INTRODUCTION

A great variety of vertebrate pest situations occur in urban, agricultural, and other environments throughout the world. The resulting problems include severe economic losses, threats to human or domestic animal health, impacts on fragile ecosystems or endangered species, or simply the nuisance of undesirable animals (National Academy of Sciences, 1970). Some species occupy limited geographic ranges and cause localized damage. Others have worldwide distribution and occur in a variety of habitats. The taxonomy and distribution of many of these vertebrate pests is not well known and little is known about the ecology and behavior of some of the most important pest species. Until recently, most of the concern with vertebrate pest problems has been directed toward the temperate, urban areas of the world. Most vertebrate control materials were originally developed for use in these situations.

Increasing food production is one of the most important challenges facing mankind. In some developing countries, a wide disparity exists between available food and human population numbers, despite the fact that about one-half of the world's population is actively engaged in agriculture. Millions of people in scores of nations still suffer hunger, malnutrition, and starvation. The reasons are many and complex, but certainly vertebrate pests (primarily rodents and birds) are important factors.

Historically, vertebrates have not received the degree of attention given to other agricultural pests. Damage by vertebrate pests is, however, unquestionably calculated in hundreds of millions, perhaps billions of dollars, annually. Nearly all the food crops grown on small farms are susceptible to bird and rodent damage from planting until consumption. Because animals may concentrate in ripening or preferred crops, heavy damage can occur in a few days. Intensified agriculture and diverse cropping patterns allow pest species to move to new feeding areas when a particular crop is harvested. Populations of birds, and particularly rodents, are often less stable in agricultural areas than in urban situations where much of the vertebrate pest control research has taken place. Population reduction programs are often ineffective in reducing damage in agricultural areas. Although many animals might be killed by a one-time application of a rodenticide or avicide, new animals quickly move in to occupy the vacant area and exploit its resources–the farmer's crop. In recent years, more emphasis has been placed on developing techniques and programs which protect crops directly, on reducing the influx of animals into crop fields, or on reducing specific, local pest populations associated with a loss problem.

TYPES OF DAMAGE SITUATIONS

We will describe a few examples of the many types of agricultural damage caused by rodents and birds. Jackson (1977), Hopf et al (1976), and De Grazio (1978) provided more detailed information on a great variety of damage problems caused by rodents and birds. Different pest species or groups may be implicated, depending on the kind of crop or geographic region. Because species have different reactions to management methods, local research and evaluation are generally necessary before recommendations can be made on a specific problem. Likewise, management techniques and programs must be compatible with the social, economic, philosophical, and religious situations of the villages or areas where they would be used.

Rodent pests

Emerging and maturing grain

Numerous rodent species damage emerging and maturing grain crops throughout temperate and tropical regions (Sanchez, 1975). Damage occurs in two patterns, one superimposed on the other. Chronic damage commonly occurs every year in every area, but with consider-

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able variation in incidence and magnitude of damage and in sizes of local rodent populations. Less common, but more spectacular, is the pattern of occasional rodent "outbreaks" which occur with some species in some environments. In such situations, exceptionally high rodent populations may build under favorable environmental conditions and cause heavy crop destruction over wide areas. Irrigated fields may be particularly affected during dry periods when rodents from surrounding natural areas move to these last reservoirs of food and cover. Usually, such situations do not persist for more than one or two seasons since animals cannot maintain high population levels during intercrop periods (Fall, 1982).

Few surveys have been conducted to assess damage over broad areas. Fall (1982) summarized surveys conducted in nearly 1 600 ricefields in the Philippines over a three-year period (1970-1972). Damage, principally by ricefield rats, averaged about three to five percent of the total stems at harvest, although yield loss was probably underestimated by this technique. Ninety percent of the fields surveyed had detectable rodent damage, ranging as high as 58 percent of total stems. Poche et al (1982) reported a national survey of wheat damage by lesser bandicoot rats (*Bandicota bengalensis*) in Bangladesh. Little damage occurred in the early growth stages, but damage to mature wheat was estimated at 12.1 percent or 77 000 tons of grain. Similar but less extensive surveys of wheatfields in Nepal revealed damage averaging 7.2 percent (Fall 1975). Web-footed rats (*Holochilus brasiliensis*) and cotton rats (*Sigmodon hispidus*) are primary rodent pests in Latin America; rice loss in Venezuela alone may be US $40 million per year (Leon, 1985; Williams, 1984).

Coconuts and sugarcane

Rodent problems with coconuts and sugarcane have received considerable attention (Taylor, 1972). Rats feed on and damage developing nuts in many tropical countries of the world. As in many rodent damage situations, damage may be localized, varied annually or seasonally, and related to a variety of environmental factors and agricultural practices. In the Tokelau Islands, Wodzicki (1973a) estimated losses of up to 84 percent by Polynesian rats (*Rattus exulans*) on his study plots. Williams (1974) found losses in Fiji between 1970 and 1972 to range from 5.6 to 13.3 percent. In the Philippines, which supplies the majority of the world's copra exports, coconut oil (Woodroof, 1979), and dessicated coconut (Anon., 1975), rats are implicated as a limiting factor for coconut production in some areas (Fiedler et al., 1982). However, based on the results of almost a decade of studies, it appears that baiting the crowns of a portion of trees in groves has the potential of providing highly economical protection and substantially increased yields (Fiedler et al., 1982).

Sugarcane is damaged by rats wherever it is grown. Rodents gnaw the internodes, particularly of the less fibrous varieties, and feed on the sweet tissues within. The sugar content of canes decreases after rodent damage as a result of secondary bacterial and fungal growth (Taylor, 1972). Hampson (1984) estimated that US $518 million of world cane sugar production is destroyed annually by rodents. Losses as great as 21 percent in cane weight and 15 percent in sucrose content have been demonstrated in Hawaii (Pemberton, 1925), Guyana (Bates, 1969), and Mexico (Collado and Ruano, 1962). In Barbados, the loss in weight of cane during one year was six percent (Taylor, 1965), and on Negros Island in the Philippines about seven percent stalk damage equivalent to about two percent total sugar loss was found (Estioko, 1978, 1980). Hood et al. (1971) found that in Hawaii damage began when the cane was about 14 months old, then increased rapidly to a peak at 19 to 21 months. In their 5.7-hectare plot, 29 percent of the crop was lost to Polynesian, Norway (*Rattus norvegicus*), and black rats (*Rattus rattus*).

Root crops and vegetables

In Senegal, rodents are known to damage both groundnuts and several kinds of vegetables. Groundnuts are often left in the fields to dry for a considerable period after harvest. Before being transported for processing, they may be held for additional time at open storage depots. During these periods of unprotected drying and storage, losses to rodents continue. Some rodent species store groundnuts in their burrows. D'jrra (personal communication) reported an assessment in which four villages in the vicinity of Louga, Senegal, showed an abundance of about 2 000 rodent burrows and 35 kg of cached groundnuts/ha, amounting to about six percent of the groundnut production of these villages in 1976. In another village, it was reported to one of us (Fall) that of a 600-kg/ha groundnut harvest, rodents had stored 100 kg/ha underground, whereas in another part of the same district, villagers reported losses of most of the groundnut crop after harvest.

Damage in small plots of tomatoes, potatoes, beans, cabbage, and carrots is widespread. Depending on the crop stage, either vegetative growth or the edible fruit is damaged. Garden plots received heavy rodent pressure during the 1976 rodent outbreak in Senegal because the plots were usually surrounded by large uncultivated areas from which rodents could move to feed.

Sweet potato and cassava (manioc) are frequently damaged by rats in Asia, Africa, and Latin America. The long period of susceptibility during maturation, accessibility to burrowing rodents and preference by many species contribute to this damage. Losses of 5 to 10 percent in West Africa, up to 15 percent in Central Africa and 30 percent in the Pacific Islands have occurred (Meehan, 1984). Yams, taro, white potato and several other root crops are also susceptible to damage.

Forest crops

Rodent damage to agroforest systems occurs worldwide but is not well-defined in the tropics. Fiedler (1987) summarized reported forestry and plantation crop rodent damage to seeds, seedlings, roots, bark, and fruit. Ten percent of young paw paw trees in Zimbabwe were chewed by porcupines (*Hystrix* sp.), and up to 50 percent of young cypress and pine trees in Uganda were girdled by *Otomys* sp. and *Lophuromys* sp. (Hopf et al., 1976).

Equipment and structural damage

Rodents may indirectly hinder agricultural production by damaging production equipment. In Senegal, in areas when rodent activity was high, the plastic hose or tubing used in drip irrigation systems was frequently gnawed. This problem was reported in small village gardening projects as well as on the large vegetable operations where many kilometers of irrigation tubing were involved. Irrigation dikes are often damaged by the burrowing activities of rodents.

Research farms

Rodent damage at tropical research stations wastes a considerable amount of research time and money. For example, loss of research data at a large experimental rice farm in the Philippines was estimated at about US $370 000 in 1980 (Ahmed et al., 1987).

Bird Pests

Emerging and maturing grain

In the Latin American countries of Guyana, Guatemala, Colombia, Uruguay, and Mexico, emerging rice, corn, soybeans, wheat, and sunflowers are damaged by blue-winged teal (*Anas discors*), great-tailed grackles (*Cassidix mexicanus*), eared doves (*Zenaida auriculata*), and brown-headed cowbirds (*Molothrus ater*) (Grist and Lever, 1969; De Grazio and Besser, 1970; De Grazio and Besser, 1975). Eared doves caused losses to emerging wheat equivalent to US $250 000 in Uruguay during 1971 (De Grazio and Besser, 1975). One of the most ubiquitous problems is damage to sprouting rice by white-faced tree ducks (*Dendrocynga viduata*) in Argentina, Colombia, Nicaragua, Surinam, Uruguay, and Venezuela. Rice losses of $7 million were attributed to black-headed weavers (*Ploceus cucullatus*) in the Dominican Republic in 1971 (Fitzwater, 1973; Pena, 1977). Dickcissels (*Spiza americana*) are important pests of rice in Colombia, Mexico, Costa Rica, Trinidad, and Venezuela (De Grazio, 1978; De Grazio and Besser, 1970) where growers have considered the species as a virtual plague.

Bird damage to ripening cereal crops in Africa represents losses of many millions of US dollars annually. The red-billed quelea (*Quelea quelea*), perhaps the most destructive bird pest in the world, affects the economies of more than 25 African nations. The grains most often damaged by quelea and other ploceid weavers are sorghum, millet, wheat, and rice. Minimum estimates of annual losses in eastern Africa range from $1 to 6.3 million in each country for which reliable estimates are available (Anon., 1981). Losses in Senegal are valued at $4 to 5 million (Bruggers and Ruelle, 1981). Other birds damaging maturing grains in Africa include doves, starlings, sparrows, parrots, and bishops. Tree ducks (*Dendrocygna* spp.), ruffs (*Philomachus pugnax*), black-tailed godwits (*Limosa limosa*), and sparrow larks (*Eremopterix leucotis*) damage newly sown and emerging rice and wheat in Cameroon, Senegal, and Sudan (De Grazio et al., 1971; Bruggers, 1979; Hamza et al., 1982). In Senegal, losses to newly sown rice in a government rice scheme of about 7 000 ha in the Senegal River Valley apparently exceeded 15 percent during 1975; often, entire areas have to be resown. Trecca (1975) has confirmed considerable localized aquatic bird damage to sown seeds in this river valley.

Rice is the grain most often damaged in Asia. The principal pest species include munias, parakeets, sparrows, and weavers. In Pakistan, 20 percent of a rice crop was reported lost to white-headed munias (*Lonchura maja*) (Grist and Lever, 1969; Khan, 1974). Damage in excess of 50 percent is common in maize fields frequented by rose-ringed parakeets (*Psittacula krameri*) (Bashir, 1978). Comparable and sometimes even greater damage has been reported to rice and sorghum fields in India (Shivanarayan, 1980). Emerging cereal grains were attacked in Nepal by parakeets and munias (Fall, 1975) and in Bangladesh by house sparrows (*Passer domesticus*), Indian mynas (*Acridotheres tristis*), crows (*Corvus* spp.), and doves (Poche et al., 1980). Despite this seemingly extensive list of damage situations, losses in Asia are probably considerably less than in Latin America and Africa.

Oilseeds and fruits

Oilseeds, particularly sunflower, usually are damaged by birds wherever they are grown. In some provinces of India and Pakistan, rose-ringed parakeets are considered a major constraint to sunflower production (Bashir, 1978). In India, sunflower damage may reach 100 percent if the fields are not protected (Shivanarayan, 1980). In Pakistan, parakeets may prevent farmers from trying to grow promising oilseed crops or cause them to abort their production attempts after only a single trial (Roberts, 1974). Pakistan presently produces only 50 percent of its annual cooking oil needs. Agriculturists in Pakistan are trying to close the gap between oilseed production and consumption, which is currently costing the country $239 million, but finding methods of reducing bird damage will be imperative to their success (J.F. Besser, pers. commun.). In Latin America, psittid damage to sunflowers is widespread, occurring in Argentina, Bolivia, Brazil, Paraguay, and Uruguay. Damage to sunflowers is also caused by the house sparrow and Spanish sparrow (*Passer hispaniolensis*) in Morocco (De Grazio, 1978).

Bird damage to fruit is primarily a problem of economic concern in the United States, Canada, and Europe. However, many species of birds damage various fruits crops in other countries. In Latin America, monk parakeets (*Myiopsitta monachus*) damage a variety of fruits in Argentina, Bolivia, Brazil, Paraguay, and Uruguay. The brown jay (*Psilorhinus mexicanus*) is implicated in fruit damage in Costa Rica. Psittids attack mangoes in Honduras and Mexico. In Northeast Africa, the European starling (*Sturnus vulgaris*) and a thrush (*Turdus* sp.) damage olives and the white-vented bulbul (*Pycnonotus barbatus*) is a problem on other fruits. In Senegal, starlings damage ripening tomatoes. Various sparrows and weavers are a problem in Sudan. In Tunisia, the European starling damages olives to the extent of 15 000 metric tons per year (De Grazio, 1978). In Pakistan, red-vented bulbuls (*Pycnonotus cafer*) and parakeets are problems with apples, pears, plums, and persimmons, and the black bulbul (*Hypsipetes madagascariensis*) with apricots and peaches in the Northwest Frontier Districts (Ali and Ripley, 1969; J. F. Besser, pers. commun.). Losses to fruits in Bangladesh are caused by parrots, finches, and crows.

MANAGEMENT METHODS

No single method or approach to reducing agricultural losses to vertebrate pests is applicable in all damage situations. Even under ideal conditions, the results of most methods are variable. A great variety of vertebrate pest management materials, methods, and techniques have been used or suggested for any particular pest situation. Proposed methods must not only be effective in reducing damage, but should also be evaluated for safety to humans and nontarget animals, cost, practicality, environmental effects, acceptability to farmers, and availability of materials. Unfortunately, the effectiveness of many potential crop protection methods has not been evaluated in many different situations. The remainder of this paper briefly discusses some of these methods. For simplicity, methods will be grouped in the broad categories of physical, chemical, and biological. Use of product names is for identification only and does not imply U.S. Government recommendation of specific materials.

Rodents

Physical methods

Trapping, digging or flooding burrows, drives, and other methods of capturing and killing rodents are often very popular activities with some farmers, but are not particularly useful except on small farms with localized damage because of costs and labor demands. The excellent cover in crop fields during growing season makes capturing a very high percentage of a rodent population difficult. Rapid reinvasion of fields may also reduce the effectiveness of these methods. If such activities are carried on after harvest when rats are easy to capture and kill, the local population can generally rebuild (by reproduction or immigration) in time to damage the next crop (Fall, 1977).

Barriers to exclude rodents from fields can be extremely effective in preventing damage in some situations, but designing effective barriers requires considerable knowledge of the behavior of the species. Both lethal (Ramos, 1967) and nonlethal (Reidinger et al., 1985; Shumake et al., 1979) electric fences have been used in several farming and experimental situations (Ahmed, 1981) in the Philippines. Cost, maintenance difficulties, and the need to remove animals enclosed within the barrier are often problems which inhibit their widespread use. Theoretically, the relative cost of crop protection with lethal and nonlethal electric fences decreases substantially when areas of 20 ha or greater are enclosed (Shumake et al., 1979). If barriers are proven effective on large areas, their costs could be projected in the same range as costs for baiting with rodenticides.

Biological methods

Biological control methods for rodents have been a major topic of discussion for many years among people concerned with rodent damage, but little research has been conducted. The biological methods most frequently suggested as approaches to rodent control include the introduction of predators, diseases or parasites; genetic manipulation; habitat modification to lower carrying capacity; and less susceptible crop varieties. Most of these approaches suffer from theoretical or practical difficulties (Fall, 1977). For example, reducing rodent harborage could be a highly effective way to lower the carrying capacity of an environment for rodents and maintain low population levels. Unfortunately, this is extremely difficult to accomplish in agricultural situations because the crop itself provides both food and cover. Field sanitation (weed control, removal of postharvest debris, and minimizing numbers or sizes of dikes, field borders or other places for rodents to burrow) may be a useful supplement to other control methods, but would generally not be effective in reducing damage in grain fields if used alone.

Predator, parasite, and disease introductions are not effective techniques for rodent control. Rats, humans, and domestic animals share many of the same diseases, making research on such methods a potentially hazardous proposition. Research done in earlier years suggested that long-term reduction of rodent populations by introduced diseases would probably be impossible without means of maintaining highly pathogenic strains of disease organisms and preventing the development of disease resistance within the rodent populations (Davis and Jensen, 1952). Experimental introduction of rodent predators has not been successful as a control method (Wodzicki, 1973b). Vertebrate predators depend on an abundant, stable food supply to survive and raise young, which the variable rodent populations in crop fields do not provide. Introduced predators have often become serious pests themselves, killing domestic fowl, threatening the survival of desirable wildlife species, or becoming reservoirs of human or domestic animal diseases (Kramer, 1971). Encouraging natural predation to supplement chemical control may be beneficial in some situations (Lenton, 1980).

Chemical methods

The use of rodenticides has proven to be a relatively inexpensive way to reduce rodent damage. It is important, however, that the rodenticides are evaluated relative to the degree of protection they give to the crops, not from the viewpoint of rodent mortality. It is also important to recognize that physiological and behavioral differences among rodent species can produce great variations in the effectiveness of particular toxicants or formulations.

Most rodenticides are used in bait formulations; the selection of a suitable formulation for a particular species in a particular crop habitat is of great importance. Use of locally available bait material is highly desirable. Bait containers may be necessary to prevent access to bait by nontarget animals or people and to provide some protection from rain. Bait containers can be made from cheap, locally available materials to reduce costs, but must not prevent or reduce availability of the bait to the rodents causing damage (West et al., 1975; Fall, 1977).

Rodenticides may be generally categorized as acute or chronic. Acute rodenticides, such as zinc phosphide, are relatively fast-acting materials which kill rodents after one feeding. These materials often require the use of prebaiting to assure that a higher percentage of the rodent population will receive a lethal dose of the rodenticide at the first feeding. Animals which receive sublethal doses often associate their illness with the toxic bait and become bait shy. The development of bait shyness in surviving animals usually limits the value of repeated treatments. West et al. (1972) found that in the Philippines, zinc phosphide bait applications were of little use in protecting ricefields from damage by rats, possibly due both to bait shyness and rapid reinvasion of treated fields. Thus, agricultural uses of such materials might be more appropriate in situations such as seed beds, where rapid reduction of a rodent population is desirable to minimize the cost of subsequent control methods, where the period of crop damage is sufficiently short that a single treatment could be effective, or where rodent populations recover slowly in relation to the growing period of the crop making periodic treatment feasible. Under such conditions, periodic use of zinc phosphide was an effective means of reducing rat damage to sugarcane crops in Hawaii (Hilton et al., 1972) and to wheat in Bangladesh (Brooks et al., 1985).

The second general category of rodenticides is the chronic toxicants or anticoagulants such as warfarin, diphacinone, and coumatetralyl, which act by reducing the clotting ability of blood. They are offered in low doses over a period of several days. Because daily (multiple) doses generally are necessary to gain toxic effects, the chances of accidental poisoning of nontarget animals are reduced (Fall, 1977). The same delay in the development of intoxication avoids the problem of bait shyness, because rodents appear unable to associate toxic symptoms with the bait material. Thus, these materials are suitable for baiting throughout the crop period. A series of experiments with anticoagulant baits throughout the crop period (Sanchez et al., 1972, 1973, 1974; Sanchez and Reidinger, 1980; Fall, 1982) indicated that rat damage to rice crops on individual small farms could be substantially reduced by this approach. It appeared critical that baiting be started soon after planting, that enough bait stations be used to avoid competition among rats, and that an excess of bait be maintained at the stations. Baiting could be stopped one to two weeks before harvest and then resumed during the next crop (Reissig et al., 1985). This approach has been termed "sustained baiting" (Fall, 1982).

Two serious disadvantages are apparent in using anticoagulant rodenticides for agricultural rodent control on small farms. Large amounts of bait material are needed to reduce severe rodent damage (because animals may continue feeding for up to two weeks), and farmers see few dead animals (because the rodents become ill slowly, they generally die in burrows or among plant cover—not near bait containers).

Several newer anticoagulant rodenticides now being marketed in some countries may help eliminate the requirement for large amounts of bait (Dubock, 1982). These materials (for example, brodifacoum and bromodialone) are toxic to some rodent species with a single feeding. Lethal symptoms still require several days to develop, and bait shyness does not become a problem. Flocoumafen (Johnson, in press), a single-feed anticoagulant, and bromethalin (Spaulding, 1987), a non-anticoagulant lethal in two to three days after a single feeding, are two chemicals that soon may be available in developing countries. As with multiple-dose anticoagulants, secondary hazards may be a problem in some situations where these new rodenticides are used (Kaukeinen, 1982; Colvin et al., in press).

When rats live in burrows or other confined spaces, fumigants are often used for localized control. Calcium cyanide dust, aluminum phosphide tablets, or gas cartridges that produce carbon monoxide when ignited in burrows are among the most commonly used materials. Fernando et al.,(1967) tested commercial aluminum phosphide tablets for fumigating burrows of mole rats (*Bandicota bengalensis (Gunomys gracilis)*) in ricefields in Sri Lanka. From the several approaches tested, they concluded that one-half of a three-gram tablet placed into one exposed burrow in each dike section was adequate to control resident animals. The procedure worked best in dikes that had not yet begun to dry and crack. More recently, Savarie et al. (1980) developed a two-ingredient gas cartridge containing 65 g of a mixture of sodium nitrate (65%) and charcoal (35%) which was found to be as effective as existing cartridges with more complex formulations. In field tests conducted at a rat-infested cattle feedlot, average reduction was 77 percent (35 to 95% range) in numbers of reopened burrows after fumigation as compared with pretreatment figures.

Rodent burrows are sometimes fumigated by introducing exhaust gases of tractor engines or smoke from burning or smoldering materials. Introducing smoke from a burning mixture of rice straw and sulfur is a widely practiced fumigation technique in Indonesia. Although fumigation can be an effective means of killing burrowing rodents, its effective use to protect crop areas is limited to situations where a major proportion of the pest population occupies accessible burrows during the day and where rapid reinvasion is unlikely.

Birds

Traditional and physical methods

In many countries, field guards or bird scarers are employed to chase birds from fields by patrolling and using a variety of visual or auditory frightening methods such as gourds, cans, drums, rattles, or cracking whips. With proper timing, persistence, and the use of combinations of methods, such an approach can be effective in some situations. However, effectiveness is subject to such variables as the season, the type and maturation stage of the crop, the pest species and its abundance, the size and ownership of the field, and the diligence and enthusiasm of the bird scarers (Ruelle and Bruggers, 1982). Some of the physical methods for reducing bird damage include the use of traps, netting, guns, exploding shotgun shells, carbide or propane exploders, or broadcasting noise or recorded bird distress calls from stationary units or moving vehicles. Monofilament line and reflecting ribbon strung over problem areas have each been effective in excluding some pest bird species (Blokpoel and Tessier, 1983; Bruggers et al., 1986). Physical barriers such as nets or fibers can block the access of birds to crops and provide almost complete protection when properly mounted and maintained. However, in several trials in Africa the cost of using nets ranged from $1 000 to $3 000/ha, relegating their use to high-value crops (Bruggers and Ruelle, 1982). Parotraps, modified Australian crow traps, have been used in Pakistan to trap rose-ringed parakeets from crop fields with some success (Bashir, 1979).

Chemical repellents

Relatively few chemicals have been registered in the U.S. for bird control. Methiocarb [3,5-Dimethyl-4-(methylthio) phenol methylcarbamate–Mesurol[R]] is a broad-spectrium bird repellent which is effective in repelling some birds from seeds, ripening grain, and fruit. When consumed by a bird it apparently causes a postingestional disturbance. Birds learn to avoid treated crops, but are not killed (Rogers, 1974, 1978). Field studies in Sudan (Hamza et al., 1982), eastern Africa (Bruggers et al., 1981), Senegal (Bruggers, 1979), and several other countries of the world (Crase and DeHaven, 1976) indicate that effective crop protection against some birds can be achieved by using relatively low levels and economical application techniques. Avitrol[R], or 4-Aminopyridine, is a chemical frightening agent that generally is lethal to many species of birds that eat treated bait particles; however, in some pest species it causes affected birds to emit distress calls and fly erratically. This behavior frightens other birds from baited fields. When used as a frightening agent, Avitrol is generally applied in a diluted bait with only a relatively small proportion of bait particles treated with the chemical. This technique is effective because only a few affected birds frighten the entire flock, and the amount of chemical required is reduced. It has had some success in reducing damage by dickcissels in Latin America (Besser et al., 1970; Calvi et al., 1976) and by other species in other countries of the world (Besser, 1978).

Biological methods

One of the most effective memthods for reducing damage by migratory bird species is to adjust planting schedules. Elliott (1979) found that in Chad and Cameroon the planting time of irrigated rice could be regulated so that harvest occurred before migrating quelea arrived in the area; under these conditions, damage was less than one percent. Other methods include changing crops, planting attractive decoy crops to divert bird feeding flocks, manipulating habitat (burning roost vegetation or destroying or thinning roost trees), and use of resistant crop varieties. Doggett (1957), however, stated that "bird resistance" is a relative term and noted the improbability of developing strains of sorghum that would be immune to bird attack in the absence of alternate food. Nevertheless, certain plant characteristics such as loose and pendant heads, awns, large glumes, and astringency may offer possibilities for selecting varieties less susceptible to damage (Bullard and York, 1985).

MANAGEMENT PROGRAMS

A variety of biological, ecological, social, and economic factors must also be considered in devising such programs. Fall (1980) identified four basic questions that should be answered to amck initial program decisions: (1) Who will carry out control? (2) What are the primary areas or units in which control would be carried out? (3) What basic control approach is appropriate? (4) What control methods should be considered? Different pest situations with differing ecological, social, and economic conditions might lead to different answers even if the same pest species and crop were involved. For example, in one situation a program to be used by a progressive farmer in protecting an individual wheat crop from bird damage might be warranted. In another situation a program to protect wheat crops of subsistence farmers in an entire district from damage by the same bird species might be needed. The program approaches, the methods chosen, and the costs entailed could be very different in these two situations, but both programs might be considered effective.

Developing and evaluating management program is, without doubt, of equal importance with describing damage situations and devising control methods and techniques. But this essential area has received much less attention. Continuing efforts should be made by all concerned with crop damage by vertebrate pests to think beyond our traditional research areas. Our challenge during the next few years is to devise, test and implement programs to reduce crop losses, using the substantial information already available.

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